Energy deposit

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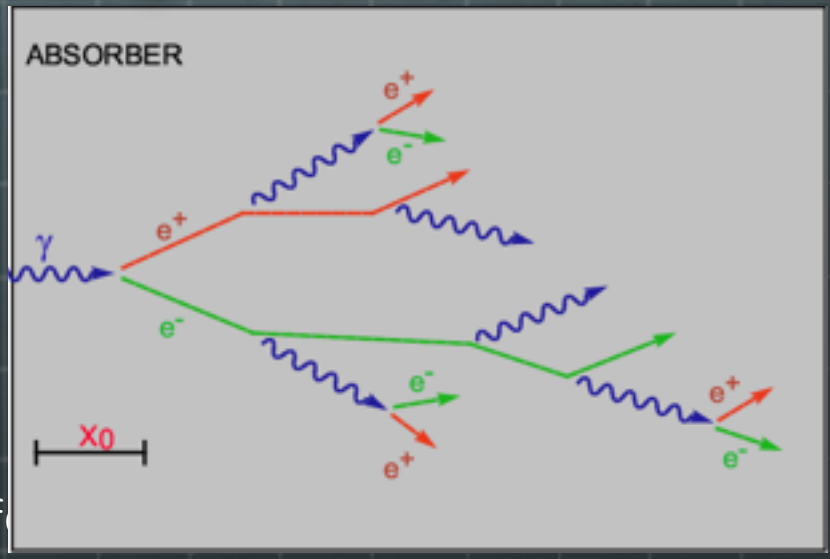
Electromagnetic shower

- Electromagnetic calorimeter uses a successive generation of secondaries - EM shower.
- High energy photon occurs pair creation dominantly.
- High energy electron-positron pair loses its energy by bremsstrahlung.



Radiation Length (Xo)

- Characteristic amount for energy loss of (high energy) photon and electron
  - mean distance over which a electron loses its energy as 1/e by bremsstrahlung
  - 7/9 of the mean free path for pair production by a photon

foot notes

Longitudinal shower development

- Number of secondaries

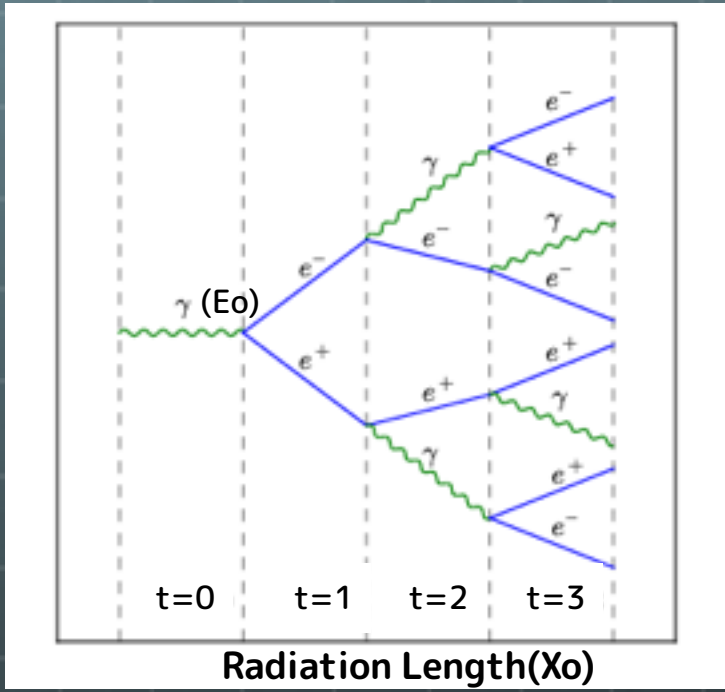
$$N = 2^t$$

- Average Energy

$$E(t) = E_0/2^t$$

- Shower development stops at

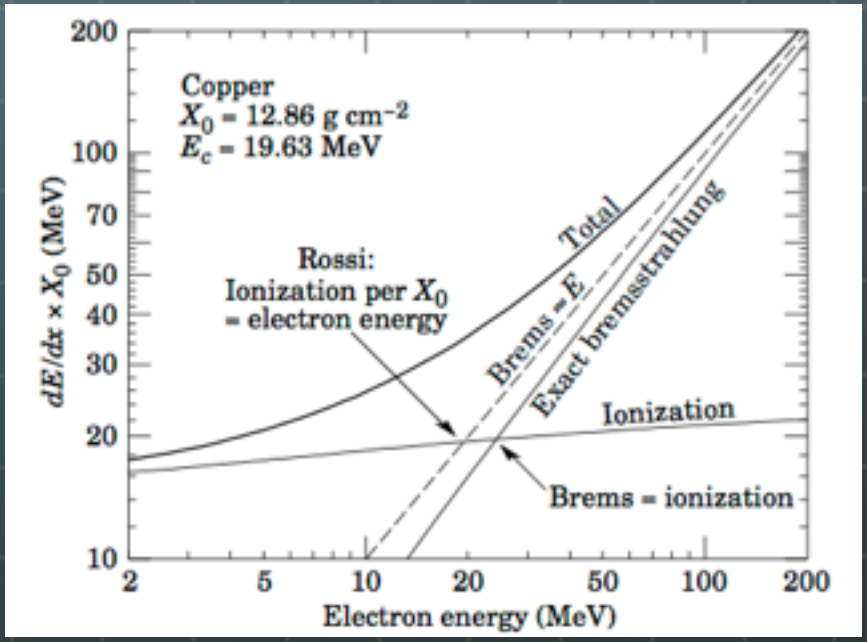
$$E(t) = Ec$$

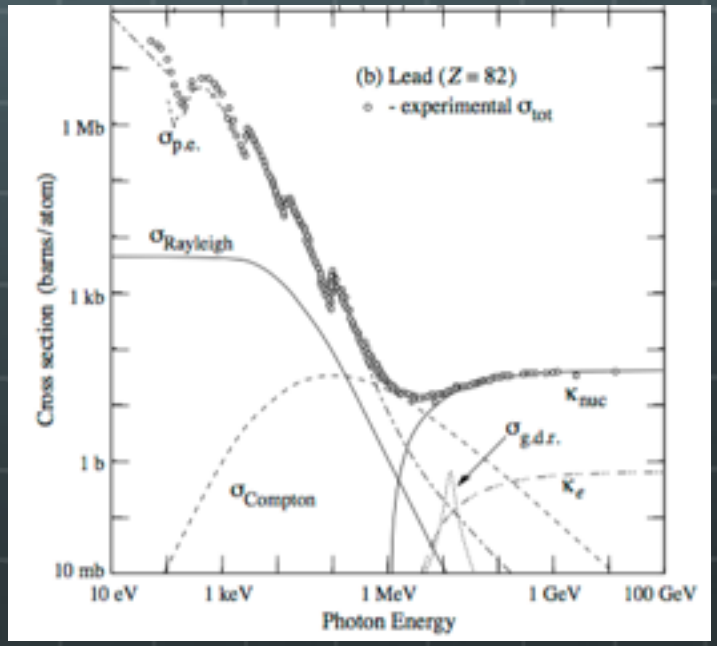


foot notes

Critical energy (Ec)

- Energy at which a electron losses its energy as same amount by bremsstrahlung and ionization.
- Energy at which the ionization loss per Xo is equal to the electron energy.





Atomic and nuclear properties of copper (Cu)

Quantity	Value	Units	Value	Units
Atomic number	29			
Atomic mass	63.546(3)	g mole^{-1}		
Specific gravity	8.960	g cm^{-3}		
Mean excitation energy	322.0	eV		
Minimum ionization	1.403	MeV g^{-1}cm^2	12.57	MeV cm^{-1}
Nuclear collision length	84.2	g cm^{-2}	9.393	cm
Nuclear interaction length	137.3	g cm^{-2}	15.32	cm
Pion collision length	109.3	g cm^{-2}	12.20	cm
Pion interaction length	165.9	g cm^{-2}	18.51	cm
Radiation length	12.86	g cm^{-2}	1.436	cm
Critical energy	19.42	MeV (for e^-)	18.79	MeV (for e^+)
Molière radius	14.05	g cm^{-2}	1.568	cm
Plasma energy $\hbar\omega_p$	58.27	eV		
Muon critical energy	317.	GeV		
Melting point	1358.	K	1085.	C
Boiling point @ 1 atm	2835.	K	2562.	C

For muons, $dE/dx = a(E) + b(E)\,E$. Tables of $b(E)$: PDF TEXT
Table of muon dE/dx and Range: PDF TEXT
Explanation of some entries
Table of isotopes Warning: may not be current
x ray mass attenuation coefficients

aterials

) tables including radiative losses for muons, nuclear and pion
us, plasma energy, and links to isotope and x-ray mass atteunation

aterials.

					$_{2}$He
$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	$_{9}$F	$_{10}$Ne
$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{31}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{35}$Br	$_{36}$Kr
$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{113}$Nh	$_{114}$Fl	$_{115}$Mc	$_{116}$Lv	$_{117}$Ts	$_{118}$Og
$_{68}$Er	$_{69}$Tm	$_{70}$Yb	$_{71}$Lu		
$_{100}$Fm	$_{101}$Md	$_{102}$No	$_{103}$Lr		

/2016/AtomicNuclearProperties/

PDG
particle data group

Atomic and Nuclear Properties of Materials
for more than 300 materials

Click on element or other materal for properties of interest in high-energy physics: stopping power (<-dE/dx>) tables including radiative losses for muons, nuclear and pion collision and interaction lengths, electron, positron, and muon critical energies, radiation length, Moliere radius, plasma energy, and links to isotope and x-ray mass atteunation coefficient tables and plots.

This AtomicNuclearProperties page is upgraded as needed in response to suggestions and requests for new materials.
Suggestions and comments are welcome. Please report errors.

Chemical elements: For entries in red, a pull-down menu permits selection of the physical state.
Cryogenic liquid densties are at the boiling point at 1 atm.

$_0$n																
$_1$Ps																
$_1$H																$_2$He
$_3$Li	$_4$Be											$_5$B	$_6$C	$_7$N	$_8$O	$_9$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg											$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	$_{23}$V	$_{24}$Cr	$_{25}$Mn	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	$_{29}$Cu	$_{30}$Zn	$_{31}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{35}$Br	$_{36}$Kr
$_{37}$Rb	$_{38}$Sr	$_{39}$Y	$_{40}$Zr	$_{41}$Nb	$_{42}$Mo	$_{43}$Tc	$_{44}$Ru	$_{45}$Rh	$_{46}$Pd	$_{47}$Ag	$_{48}$Cd	$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{55}$Cs	$_{56}$Ba	$_{57}$La	$_{72}$Hf	$_{73}$Ta	$_{74}$W	$_{75}$Re	$_{76}$Os	$_{77}$Ir	$_{78}$Pt	$_{79}$Au	$_{80}$Hg	$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{87}$Fr	$_{88}$Ra	$_{89}$Ac	$_{104}$Rf	$_{105}$Db	$_{106}$Sg	$_{107}$Bh	$_{108}$Hs	$_{109}$Mt	$_{110}$Ds	$_{111}$Rg	$_{112}$Cn	$_{113}$Nh	$_{114}$Fl	$_{115}$Mc	$_{116}$Lv	$_{117}$Ts	$_{118}$Og
		$_{58}$Ce	$_{59}$Pr	$_{60}$Nd	$_{61}$Pm	$_{62}$Sm	$_{63}$Eu	$_{64}$Gd	$_{65}$Tb	$_{66}$Dy	$_{67}$Ho	$_{68}$Er	$_{69}$Tm	$_{70}$Yb	$_{71}$Lu		
		$_{90}$Th	$_{91}$Pa	$_{92}$U	$_{93}$Np	$_{94}$Pu	$_{95}$Am	$_{96}$Cm	$_{97}$Bk	$_{98}$Cf	$_{99}$Es	$_{100}$Fm	$_{101}$Md	$_{102}$No	$_{103}$Lr		

Inorganic compounds (Al through Fe) — Aluminum oxide through ferrous oxide
Inorganic compounds (Freon through Pu) — Freon through plutonium oxide
Inorganic compounds (Potassium thru yttrium) — Potassium iodide through water
Inorganic scintillators (BaF2 through Y2SiO5) — Barium fluoride through Y2SiO5
Simple organic compounds — Acetone through Xylene
Polymers — Polymers
Mixtures — Aerogel t
Biological materials — A-rnn-dimethyl_formamide through tissue-equivalent gas

http://pdg.lbl.gov/2016/AtomicNuclearProperties/

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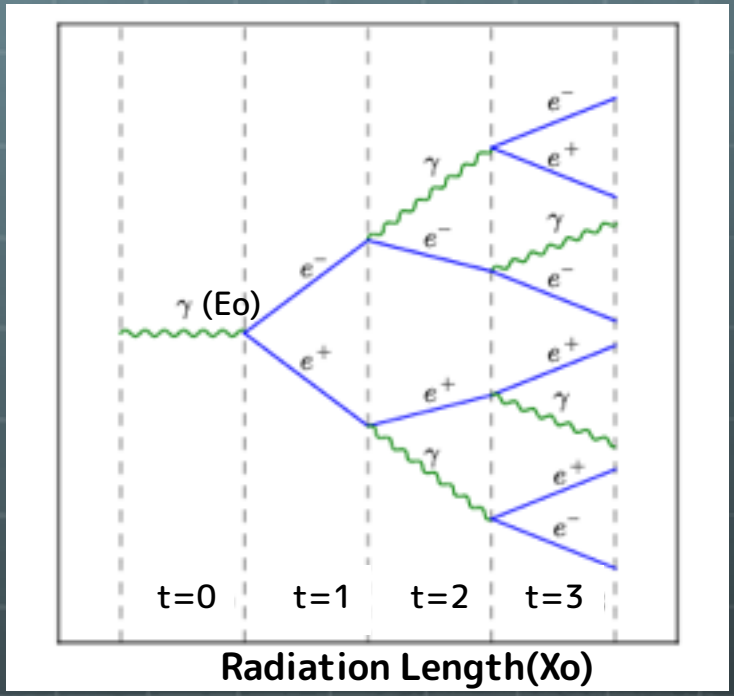

- Maximum number of shower particles at which their energy is critical energy ;

$$Ec = E_0/2^{t_{max}} \qquad t_{max} = \ln(\frac{E_0}{Ec})/\ln 2$$

foot notes

Energy deposit

- Energy deposit ∝ total integrated charged track length

$$< T_i(E_0) >= \int_{(i-1)\Delta t}^{i\Delta t} N(E_0, E_{th}, t)dt$$

$$\frac{dE}{dx} = E_0 b \frac{(bt)^{(a-1)} e^{-bt}}{\Gamma(a)}$$

$$t_{max(\frac{dE}{dx})} = (a-1)/b$$
$$= \ln(\frac{E_0}{Ec}) + C_j$$

$$C_e = -0.5$$
$$C_\gamma = +0.5$$